SUSTAINABLE AGRICULTURE - SOME COMPLICATING INTERACTIONS

C.A. Campbell*, R.P. Zentner, H.H. Janzen, R.D. Tinline, & J.R. Byers

*Research Station, Research Branch, Agriculture Canada
Swift Current, Saskatchewan

ABSTRACT

There have been numerous definitions of 'Sustainable Agriculture' put forth, but we address the official one adopted by Agriculture Canada:

> "Sustainable agricultural systems are those that are economically viable, and meet society's needs for safe and nutritious food while conserving or enhancing Canada's natural resources and the quality of the environment for future generations".

Speeches and discussions of this topic appear to be the order of the day. Depending on the source and definition, conflicting viewpoints are often expressed. Within Agriculture Canada this concept is being given top priority. In the long-run, one of our main goals is to "ensure that all government policies and programs are in harmony with the concept of sustainable agriculture" (G.A. Neish, address to Canada Grains Commission, October 24, 1989). This paper will discuss, from a research perspective, some of the inherent complexities and interactions that might make such laudable goals difficult to resolve and suggest some possible mechanisms by which their achievement may be facilitated.

- - - - - - - - - -

Results of a recent public opinion poll on several agriculture and environment related issues carried out by Environics Research Group under the Focus Canada survey are shown in Table 1.

Table 1. Results of Poll+ of Canadian Opinions on Issues Related to Agriculture and the Environment

	Degree of Concern (% of Canadians)				
ISSUES	very	somewhat	not very	not at all	don't know
Pesticide use	57	26	8	3	3
Depletion of Soil	47	33	12	3	5
Fertilizers	34	40	18	6	2
Livestock Feedlots	33	33	18	7	10

+ Source: Research & Planning Unit, Communications Branch, Ag. Canada, July 1989 (from Focus Canada Survey done by Environics Research Group in June).

The results of this poll clearly emphasize the strong opinions that Canadians currently hold concerning the degrading state of the environment and the way agricultural practices are viewed as a source of the problem. The survey also showed that 49% of Canadians feel that the Federal Government, more so than farmers, chemical companies, etc., has the primary responsibility for reducing agricultural degradation of the environment. About three in every four Canadians suggest that the preferred federal action on farm chemicals should be to do more to restrict their use; only 13% thought they are doing enough. Only 1% of Canadians felt that the Federal Government was experiencing success in promoting farm practices to protect the environment; 32% said they were somewhat successful but 36% said they were not very successful.

It is therefore not surprising when we read frequently in dispatches originating from Agriculture Canada that the concept of 'Sustainable Agriculture' is being given top priority. In the long-run one of our main goals is to "ensure that all government policies and programs are in harmony with the concept of sustainable agriculture" (G.A. Neish 1989).

The latter goal is laudable; it is clear and straight forward in its intent; but how easy is it to achieve? This will be the theme of our presentation today.

Because there are currently so many definitions of "Sustainable Agriculture" (see Agri. Science for Sept. 1989 pp 3-5), we have chosen the one officially adopted by Agriculture Canada which states:

> "Sustainable agricultural systems are those that are economically viable, and meet society's needs for safe and nutritious food while conserving or enhancing Canada's natural resources and the quality of the environment for future generations."

As you can see this is a most reasonable definition. It does not exclude the use of fertilizers, or pesticides, nor does it prescribe "organic farming" as the only approach to sustainability; nor recommend that any extreme situations be adopted. It is a definition most scientists should be able to live with and work towards. In fact, most of us will tell you that this is what we thought we were doing all along.

Nonetheless, let us now take a closer look at some of our recommended agricultural systems and management practices and see how well they meet the criteria for sustainability, and if they don't, let us consider how easy it will be to modify our cropping systems or policies so as to achieve these criteria and goals.

We plan to draw heavily on two sources: (a) part of a talk that Campbell presented to members of the Alberta Institute of Agrologists entitled "The consequences of society's move to greater use of more chemical inputs, greater mechanization, and more monoculture", and (b) an excerpt from a "crop rotation bulletin for the Canadian prairies" (Campbell et al. 1990), that will soon be published by Agriculture Canada. Both of these articles revealed that what might appear to be simple straightforward solutions to agronomic problems can often lead to unforeseen problems in other parts of the system. The bulletin was written by a group of experts with specialities in various disciplines ranging from soils to economics to pathology to agronomy and so on. As one read what each individual group was recommending as solutions to their own specific problems (i.e. in isolation from each other) it became clear that solutions to a problem in one phase of the system could easily create problems in another phase of the system.

In Table 2 we have examined five commonly used or recommended practices with regards to their possible desirable and undesirable effects on the agricultural production and environmental system.

Examples to support all the points listed are presented in the Crop Rotation bulletin (Campbell et al. 1990) and neither time nor space will allow me to support them further here. It is obvious from Table 2 that trade-offs will be necessary if we are to design systems and policies that minimize undesirable effects and maximize desirable effects, thereby leading to "sustainablity". Obviously this will not be easy.

Can we use Crop Rotations to Solve the Problems and Promote Sustainability?

Perhaps a few quotes from the Rotation Bulletin (Campbell et al. 1990) will assist us in understanding the conflicts and complexities of the problem with which we are faced:

> PLANT DISEASES
>
> "Rotation of susceptible and resistant crops is one of the oldest practices used to control disease. It remains an important practice against many diseases, particularly those for which more specific controls, such as host resistance or chemical methods are unavailable.
>
> The success of crop rotation in disease reduction is contingent upon many factors, which include the ability of a pathogen to survive in the absence of its host and the host range of a pathogen. Pathogens that live indefinitely in the soil are less likely to be curtailed by rotation of crops than those that can survive for only brief periods apart from their hosts. Similarly, pathogensthat have a wide range of hosts are less amenable to control by crop rotation than those with a narrow range. Transmission of pathogens via seeds, the presence of susceptible volunteer crops and weeds that harbor the pathogens, and the distribution of pathogens by wind and other agents may negate benefits derived from crop rotation. For example, rotation is ineffective for control of rusts in small grain cereals because the rust fungi do not overwinter in western Canada. Inoculum from the south is disseminated into the area by wind in summer, which circumvents protection by crop rotations.
>
> Typically, crop rotation is used in conjunction with other cultural practices such as tillage, fertilizer, and weed control."

Table 2. Some apparent conflicting outputs from some technologies available for use by producers (Brown Soil Zone)

System	Possible Desirable Effects	Possible Undesirable Effects or Limitations
1. Conventional Fallow	1. Buffer against drought 2. Improves net returns & reduces risk 3. Breaks some disease and insect cycles 4. Helps provide higher delivery quota 5. Provides nutrients "free"	1. Inefficient use of water 2. Loss of soluble nutrients via leaching & run-off 3. Soil erosion by wind cause loss of SOM 4. Salinity increased 5. N supplying power diminished
2. Continuous Wheat	1. More efficient water use, therefore less leaching and less salinity 2. Protects soil from water & wind erosion 3. Increases organic matter (SOM) & N supplying power of soils	1. Low net returns & more risky due to frequent drought & unfavorable distribution of precipitation 2. Requires more fertilizers, & costly herbicides for perennial weed control 3. Increase likelihood infestations of some insects (e.g., grasshoppers) & some diseases (e.g., leaf blights; take all)
3. Use of Fertilizer	1. Increases crop production & net returns 2. Increases SOM and N supplying power of soils 3. Reduces leached nitrates if used as recommended	1. May increase pollution of streams and ground waters if misused 2. May result in soil acidification
4. Use of Manure	The 3 points for fertilizers apply here 4. Slow release of nutrients & more balanced nutrient source than fert. (supplies micro nutrients) 5. Improves soil structure & tilth	The 2 points for fertilizers apply here too 3. Low in nutrient concentration thus require much larger quantities than fertilizer per unit area 4. Insufficient quantities available for use on large Saskatchewan farms 5. Unless mixed farming adopted, would be un-economical to haul from supplier to farmer 6. Odor pollution

Cont'd

Table 2. Some apparent conflicting outputs from some technologies available for use by producers (Brown Soil Zone)

System	Possible Desirable Effects	Possible Undesirable Effects
5. Zero Tillage, Snow trapping, and proper fertilization	1. Increases SOM & N supplying power	1. Results in perennial weed problem within five years
	2. May increase yields	2. Reduces net returns due to greater cost of inputs
	3. Improves soil tilth	3. Likely to increase disease & insect problems
	4. Less erosion & run-off losses	4. More likely to pollute the environment with pesticides
	5. Some extra water is conserved by snow management at little extra cost	5. Winter precipitation too low & just as unpredictable as GSP; infiltration of snow melt water often poor

INSECTS

"Crop rotations, particularly the practice of summer-fallowing, have played an important role in reducing infestations of insect pests in western Canada."

"Recropping directly into standing stubble is a practice that is liable to result in an increased incidence of insect damage."

"Reduced tillage or no-till summer fallow may not be quite as effective in reducing pest abundance as conventionally tilled summer fallow, which exposes the inactive stages (i.e. eggs and pupae) to predation and desiccation. However, in practice the differences of the various types of summer fallow on insect population levels are unlikely to be sufficient to influence the choice among alternative methods of fallowing. Conservation tillage, and particularly the accompanying increase in the amount of plant residues on the soil surface, may alter the interactions between pest and beneficial arthropods as well as affecting pesticide efficacy and persistence. Whether these effects can be influenced by crop rotation schemes is not yet known. Experience elsewhere has shown that reduced or no-tillage, particularly in conjunction with continuous cropping, often results in an increased incidence of insect damage."

SOIL QUALITY

"Concern about soil degradation has led to investigation to identify rotations that preserve soil quality over the long term. Crop residues are the primary substrate for replenishment of organic matter; thus changes in crops and their sequence in rotation can influence soil quality significantly."

" * The results confirmed the degradative effects of frequent fallowing on soil quality, evidenced by organic matter loss, depreciated organic matter quality, reduced microbial activity, and enhanced susceptibility to erosion.
 * Applications of N fertilizer lowered soil pH, but the effect was insufficient to warrant concern in the short term.
 * Inclusion of legume green manure and grass-legume forage crops in the rotation with cereals benefited soil productivity. However, soil quality maintained by these rotations usually did not exceed that under adequately fertilized continuous wheat, perhaps because of the inclusion of fallow in the cereal-forage rotations."

ECONOMIC PERFORMANCE

" * The realities of short-term economic survival will likely prevent producers from adopting rotations requiring annual cropping despite their long-term benefit to soil productivity. This situation is especially so in the Brown and Dark Brown soil zones where net returns were often much higher for rotations that included fallow.

* The major deterrents to adoption of extended crop rotations in these regions were the higher cash outlay required to purchase the additional inputs (e.g., fertilizers, herbicides, and capital items) and the high risk of financial loss resulting from highly variable weather during the growing season."

Energy Considerations

Only since the energy crisis of the early 1970s have producers considered the efficient use of nonrenewable energy in determining crop rotations.

" * The limited results on energy considerations showed that in the Brown soil zone nonrenewable energy inputs and metabolizable energy for human consumption were directly related to cropping intensity.
* Continuously cropped wheat required a near-doubling of total energy inputs compared to the 2-year fallow-wheat rotation; but, in so doing, metabolizable energy output was increased by about 35%.
* In contrast, the energy output-to-input ratios and the quantity of grain produced per unit of energy used were lowest for the continuous-type rotations and highest for the fallow-type rotations.
* Inclusion of legumes in the rotation with cereals considerably reduced the requirements for nonrenewable energy inputs, especially for N fertilizer, and thus improved energy efficiency."

What is the Solution?

Obviously we can't just 'throw our hands in the air' and say this problem is insoluble --- neither our Government, our citizens nor mankind will accept such a decision.

Despite the foregoing discussion it is plain to see that any successful approach to the solution of this problem must include greater inter-disciplinary cooperation in the conduct of research from start to end. In most cases at present, disciplines work within their own territory -- interaction usually comes at workshops and often too late. Often, the result is a set of cross signals to the community.

Secondly, the complexity of the problem demands the use of models to assist and guide us in our interpretations and decisions regarding what systems we can adopt and still "cut our losses" to a minimum; no system will be perfect. A good example of the type of model is the "Crop Rotation Chart" (Figure 1) that was developed by Manitoba Agriculture (MG-7126; Revised 1987). This "model" presents information for Plant Diseases, Weed

Control and Soil Fertility, in terms of potential problems that may be encountered for a matrix of possible crop rotations. The chart is color coded (black for weeds, blue for herbicides that can be used, green for fertility status of soil, and red for plant diseases). As well, ratings of probable intensity of problem is indicated. Notes on significant soil conservation considerations are also presented.

This "model" is an excellent starting point, but several things could be done to improve its power and utility from the standpoint of a tool for guiding us toward a more sustainable agricultural system. For example, some expression of probable economic status (relative net returns and riskiness) of the systems could be included. As well, the soil quality/soil degradation aspects could be quantified and included. Then there is a need to be able to make adjustments based on soil zones -- here we could divide the Prairies into dry areas (i.e., the Brown and Dark Brown soils) and wetter areas (the other soil zones). Obviously, all this information could not be placed on a simple sheet such as shown in the Manitoba Chart. However, we live in an age of computers and there is no reason why a computer model could not be developed to include all this information. Perhaps such a system could even be made "user friendly" and put on floppy discs for use in extension, scientific research planning, and to help safeguard the environment. The value of 'models' is not that they solve problems, which they rarely do, but that they often identify both gaps in our knowledge of the system and the components that might be amenable to manipulation.

In conclusion, we hope that we have emphasized the complexity of our agronomic systems and how difficult it will be to attain sustainable systems (even with the least restrictive definitions of sustainability). Nonetheless, if future research is structured to emphasize more team-work, with interactions of various disciplines from the planning stages to the end, perhaps more meaningful, less conflicting signals will result. The world will not be perfect, but with the aid of well-structured models that synthesize and adequately represent the current status of our knowledge, we should be able to approach sustainability and also be able to identify areas that require future research emphasis to mitigate remaining problems that stand in the way of achieving sustainability.

References

Campbell, C.A., Zentner, R.P., Janzen, H.H. and Bowren, K.E. 1990. Crop rotation studies on the Canadian Prairies. Canadian Govt. Publ. Centre, Supply & Services Canada, Hull, P.Q. (in press).

Figure 1. Parts of Manitoba's Crop Rotation Chart (Model)

a

Crop Rotation Chart

Manitoba Agriculture

Using The Chart

Herbicide residue problems appear in blue; weed problems in black; soil fertility in green; diseases in red.

Weed Control

Information provided has two letter codes. See the color coded explanation for description of each letter symbol. The code is followed by a letter indicating the relative significance of the problem and the number of years involved

Example

Symbol for TRIFLURALIN TR — Problem exists for one year

H1 — A high probability of a problem exists. See Rating of Problem Chart.

Plant Diseases

The letters **L**, **M** and **H** denote risk. **L** and **M** are low and moderate risk, where the crop is not very susceptible and or receives only slight damage or both. The damage likely to occur is less than 25 per cent. With **H** or high, risk diseases, losses over 25 per cent can occur

NOTE: Ergot is listed as a high risk for a number of cereal crops to indicate that they are highly susceptible. Actual disease losses are rarely over 5 per cent, but loss occurs due to down grading.

The number following the letter indicates the interval recommended between crops to control the disease through crop rotation. Disease incidence also depends on the fields previous disease history and on climatic conditions during the growth season. Disease development is often favoured by moist weather.

Problem Weeds and Soil Fertility Codes are explained below.

Some problems exist for up to four years. Follow crop rotation back four years to obtain complete information.

b

CROPS TO BE GROWN \ PREVIOUS CROP	BARLEY	OATS	FALL RYE	SPRING RYE	TRITICALE	WHEAT
BARLEY	SB:M1, DO:L1 RR:M2, ER:M1 NB:H1, SE:L1	RR:L1, DO:L1	RR:L1, DO:L1 ER:M1	VC:L1 DO:L1 ER:M1	DO:L1, ER:M1 VC:L1	SB:L1, RR:M2 DO:L1, ER:M1 VC:M1
OATS	DO:L1, RR:L1 VC:L1	DO:L1, RR:L1	DO:L1, RR:L1	DO:L1, RR:L1 VC:L1	DO:L1 VC:L1	DO:L1, RR:L1 VC:M1,
FALL RYE	DO:L1, ER:M1 VC:M1	DO:L1	DO:L1 SM:H1, ER:H1	DO:L1, ER:H1 VC:L1	DO:L1, ER:H1 VC:L1	DO:L1, ER:M1 VC:M1
SPRING RYE	DO:L1, ER:M1 VC:M1	DO:L1	DO:L1 ER:M1	DO:L1 ER:H1,	DO:L1, ER:H1 VC:L1	DO:L1, ER:M1 VC:M1
TRITICALE	DO:L1, ER:M1 VC:M1	DO:L1 VC:M1	DO:L1 ER:H1,	DO:L1, ER:H1 VC:L1	DO:L1 ER:H1,	DO:L1, ER:H1 VC:M1
WHEAT	SB:L1, DO:L1, RR:M2, ER:M1 VC:M1	DO:L1, RR:L1	DO:L1 ER:M1	DO:L1, ER:M1 VC:L1	DO:L1, ER:M1 VC:L1	DO:L1, HB:M1 SB:L1, RR:M2 TS:M1, ER:M1 SE:M1, HB:M1

c

Weed Control

Herbicide Residues — Code and Description

Information on herbicide residues is limited to those recommended in the Guide to Chemical Weed Control and its Addendum

Overapplication, caused by overlapping or use of higher rates of herbicide, may increase the risk of injury to the following crop. Use of nonrecommended herbicides may cause residue problems not indicated in the chart.

AL — **Ally**
Is not recommended for use in Manitoba. If Ally has been used on soils having a pH of 7.1 to 7.5 only wheat, barley, oats and fescue may be seeded the year following application. If the soil pH is 7.0 or less, wheat, barley, oats, fescue, rapeseed or flax may be seeded the year following application. Few soils in Manitoba are below pH 7.0. Either wheat, barley, oats, fescue, rapeseed, flax, alfalfa, red clover, or peas may be seeded the second season (22 months or longer) following the last Ally application. Crops other than wheat, barley, oats, fescue, rapeseed, flax, alfalfa, red clover or peas may be injured by residues three or more years following application. These restrictions severely limit cropping opportunities on Ally treated fields.

AT — **Atrazine (Aatrex; Atra-Mix)**
Atrazine may remain as a residue for more than one year after application. Only plant corn or triazine tolerant canola the year following an application of more than 0.445 kg/acre (1 lb/A). Flax, peas and fababeans have some tolerance to atrazine residue. These should be considered to follow atrazine treatments of 0.445 kg/acre (1 lb/A) or less. If flax, peas or fababeans are planted the year after applying more than 0.445 kg/acre (1 lb/A), moderate to severe injury may be expected.

AV — **Avadex BW**
Oats are sensitive to residual Avadex BW. Do not plant oats the year following Avadex BW application.

BL — **Bladex**
Bladex may leave a residue in the soil. Only plant corn, peas, flax, soybeans, potatoes, cereals, canola or sunflowers the year following Bladex application

LE — **Lexone**
Some crops are sensitive to Lexone residues when applied preplant incorporated as recommended for fababeans and potatoes. Cover crops planted for erosion control following potato harvest may also be damaged.

LO — **Lontrel**
The year after application, seed only wheat, oats, barley, rye, flax and canola. Residual carryover two years after application has not been fully evaluated. Sensitive crops, such as sunflowers, pulse crops or small seeded legumes, could be affected two or more years after application.

PR — **Princep (Simazine)**
Most annual crops are sensitive to Princep residues. Do not replant treated areas for at least two years following Princep application.

PX — **Primextra**
Contains atrazine. See comments for atrazine.

SC — **Sencor**
Some crops are sensitive to Sencor residues when applied preplant incorporated as recommended for fababeans and potatoes. Cover crops planted for erosion control following potato harvest may also be damaged.

SI — **Sinbar**
Most annual crops are sensitive to Sinbar residues. Treated areas should not be replanted for at least two years following Sinbar application.

TO — **Tordon 202C**
Replant to wheat, barley, oats, flax or rapeseed for two years following treatment. Do not plant fields treated with Tordon 202C to alfalfa or sunflowers

d

Soil Fertility — Code and Description

All crops on perennial legume breaking

FA — Available nitrogen for subsequent crops may approximate summerfallow nitrogen levels if legume breaking is done before June 30.

FB — Perennial legumes have a relatively high sulphur requirement. Test soil to determine sulphur availability for subsequent crops.

All crops on grass or grass-legume breaking

FC — Probable carryover of available nitrogen for subsequent crops may be about one-half summerfallow nitrogen levels if breaking performed before June 30.

All crops on summerfallow (except annual legumes)

FD — On the average, about 25 — 35% of summerfallow fields have inadequate soil nitrogen levels for subsequent crops. Test soil to determine nitrogen availability.

All crops following potatoes, corn, sugar beets

FF — These crops are usually heavily fertilized and when grown frequently, a high soil fertility may result. Soils should be tested for fertility levels.

All annual and perennial legumes

FG — Legumes should be inoculated with an appropriate rhizobium (nitrogen fixing) bacteria before seeding.

CONSERVATION REMINDERS

- Continuous cropping is recommended to maintain soil organic matter levels and to reduce soil erosion and degradation (example: salinization). Summerfallow is not recommended.
- Include cereals or forages in the rotation of crops producing small amounts of residue such as corn, potatoes, rapeseed, sugar beets or sunflowers to help maintain soil organic matter levels and provide residue for erosion control.
- Row crops planted up and down sloping lands greatly increase the water erosion potential. Plant row crops across slopes where possible. Continuous row crops on such land is not advisable.
- Burning of crop residues is not recommended as it destroys the source of soil organic matter and leaves the soil susceptible to erosion.
- Fall tillage operations should leave trash in an upright position on the soil surface to protect the soil from erosion and to hold snow for moisture conservation. Use cultivator type implements. Limit the number of disc operations. Do not harrow.
- When using preplant herbicides in the fall, use granular formulations to reduce soil erosion potential. Where possible, delay the second incorporation until spring.

MG-1126 (Rev. 87)

Problem Weeds — Code and Description

Individual fields may have serious weed problems limiting crop selection. Always be sure problem weeds can be controlled in the crop being planted.

Consider these major weed problems in your crop rotation decisions.

PT — **Perennial thistles**
Canada thistle and perennial sow thistle require control programs extending two to three years. Infested fields should not be planted to a crop which does not allow selective thistle control. Most fields contain some thistles. The cropping sequence should not contain two consecutive crops which do not allow selective thistle control.

MU — **Mustard**
Heavily infested fields should be planted to crops allowing for effective mustard control. Plant other fields to a sequence which allows effective control in alternate years.

VC — **Volunteer Crops**
Many crops can result in a volunteer crop problem the following year. Treat volunteer crops as weeds. If a volunteer problem is expected, select a crop that allows for selective control. The chart indicates potential problems where effective herbicides are not available for control.

RATING OF PROBLEM

	H	M	L
Volunteer Crop	Heavy competitive growth may be expected. Growth may reduce yield of crop or interfere with harvest. Adequate control measures are not available.	Moderately competitive growth may be expected. Growth may reduce yield or cause some harvest problems. Adequate control measures are not available	Light growth may be expected. Not likely to reduce yield or interfere with harvest. Available herbicides may give some control.
Perennial Thistle; Mustard		Infestations of Canada thistle, perennial sow thistle or wild mustard likely to develop if present in the field because herbicides are not available for control in this crop or the preceding crop.	
Herbicide Residue	Stand and/or yield of crop will be reduced.	Stand and/or yield of crop may be reduced.	Some stand or yield reduction may occur.

Plant Disease — Code and Description

AB **Ascochyta blight (fungus)**
- attacks lentils, peas and fababeans: symptoms are seedling blight followed by stem, leaf and pod spot.
- infested seed is discolored.
- for control use disease-free seed, crop rotation and sanitation.

BB **Bacterial Blight (Bacteria)**
- different species attack field beans and field peas. Can cause leaf and pod spots.
- control in field beans by use of pedigreed disease free seed produced in a semi-arid area.
- a one year rotation between susceptible crops breaks disease cycle since bacteria survive on infected crop debris for only one year.
- seed increase plots of field beans can be sprayed with tribasic copper sulphate (Tri cop) or cupric hydroxide (Kocide 101) for control of bacterial blight.

BL **Blackleg (fungus)**
- attacks canola/rapeseed: symptoms include shrivelled seed caused by premature ripening of plants.
- fungus is seedborne and survives winter on crop debris.
- seedborne infection may be reduced by using recommended seed treatment fungicides.

BS **Black stem (fungus)**
- attacks alfalfa and sweet clover: black discoloring of stems, leaf spotting and defoliation takes place.
- can survive on infested plant material and seed for several years.

CN **Cyst nematodes**
- infects sugar beets causing root deformity reducing production and sugar content.
- nematodes may lie dormant in soil for several years as cysts.
- also attacks canola/rapeseed and mustard.
- three to four year rotations among sugar beets, canola/rapeseed and mustard reduce nematode populations in soil.

CS **Corn Smut (fungi)**
- attacks corn.
- causes formation of black powdery galls on cobs, stems and tassels.
- corn smut galls remain viable in soil for several years.

DO **Damping off (fungus)**
- attacks cereals, corn, grasses and broadleaf crops
- causes seedling death shortly after emergence.
- alternate broadleaf crops with cereals, corn or grasses to prevent fungi buildup in the soil.

DM **Downy mildew (fungus)**
- affects mustard, turnip canola/rapeseed, sunflowers (except some hybrids) and buckwheat.
- on turnip rape malformed seed pods or stagheads form and may be accompanied by white rust, another fungus.
- sunflowers appear stunted with sterile heads.
- fungus may survive 3 - 4 years in soil.

EB **Early blight (fungus)**
- infects potatoes causing leaf spot, yellowing of leaves and defoliation.
- survives overwinter on infected plant debris.
- control using fungicide sprays.

ER **Ergot (fungus)**
- attacks cereals and grasses: black fungus body (sclerotia) forms in place of the normal kernel.
- controlled through crop rotation, use of clean seed and mowing grass headlands around field borders before flowering.
- a one year rotation between susceptible crops breaks disease cycle since sclerotia are viable for only one year.
- order of susceptibility for cereals: rye, triticale, wheat, barley and oats; brome grass, wheat grass, and fescue are highly susceptible.

HB **Head blight, fusarium (fungus)**
- affects wheat, corn.
- causes premature ripening of wheat florets, cob and stalk rot of corn
- susceptible crops should not follow each other in rotation.
- survives 1 - 2 years on crop debris.
- infected wheat seed should be treated with a seed protectant prior to planting.
- semi-dwarf and durum wheat varieties are more susceptible than hard red spring and winter wheat.

LS **Leaf spot (fungus)**
- affects broadleaf and grass crops.
- fungus overwinters on infected debris.
- fungus produces windborne spores.
- one year crop rotation between susceptible crops reduces disease carryover.